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Thermoluminescence in Natural Quartz

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Thermoluminescence of non-irradiated natural quartz from various geological origins was studied. The difference of geological occurrences of quartz was detectable from their glow peaks and the origin of the difference was discussed from various data.

Thermoluminescence of gamma irradiated quartz from different geological origins was reported in the previous paper[9] and their glow curves were different in peak intensity and peak temperature depending on the geological occurrences of quartz. In this work, thermoluminescence of non-irradiated natural quartz from various geological origins was studied and the difference in the concentrations of different crystal imperfection is discussed.

Quartz grains (100–200 meshes) were separated from various rocks by hand-picking, heavy solution and magnetic method. The thermoluminescence apparatus was the same as described in the previous report.[9] 80 mg of the sample powder was used for each measurement and the glow curve was recorded at the heating rate of about 90°C/min to 450°C.

Quartz samples from volcanic rock, quartz porphyry or granite porphyry, granite and dynamometamorphic rock showed glow curves considerably specific to the type of rock as are shown in Fig. 1 (1–2, 4–9).

Glow curves of quartz from pegmatite and hydrothermal vein did not have any definite shape but their shapes were different from sample to sample, suggesting that these rocks were formed at various growth conditions in contrast with other rocks.

Almost all samples from volcanic rock have only one glow peak in the vicinity of 245°C (Fig. 1. 1–2). Quartz from quartz porphyry or granite porphyry has two glow peaks at 175–210°C and 250–280°C (Fig. 1. 4–5) and in the most case, the latter peak is larger in intensity than the former. Contrasting to quartz from these origins, thermoluminescence of granitic quartz appears at the lower temperature. The glow peak of granitic quartz occurs always at 175–210°C, rarely lying at above 210°C (Fig. 1. 6–7).

The intensities and the positions of main glow peaks of quartz from these three types of rock are shown in Fig. 2. Plots of three different origins lie in well separated areas.

It is known that quartz including Li^+ has the glow peak at 170–180°C whereas quartz including Na^+ has the glow peak in the vicinity of 300°C, butquartz including K^+ shows no thermoluminescence.[1,2] Ichikawa[4] added various impurities (Li^+, Na^+ and Al^{3+}) by diffusion into quartz samples and observed thermoluminescence after the

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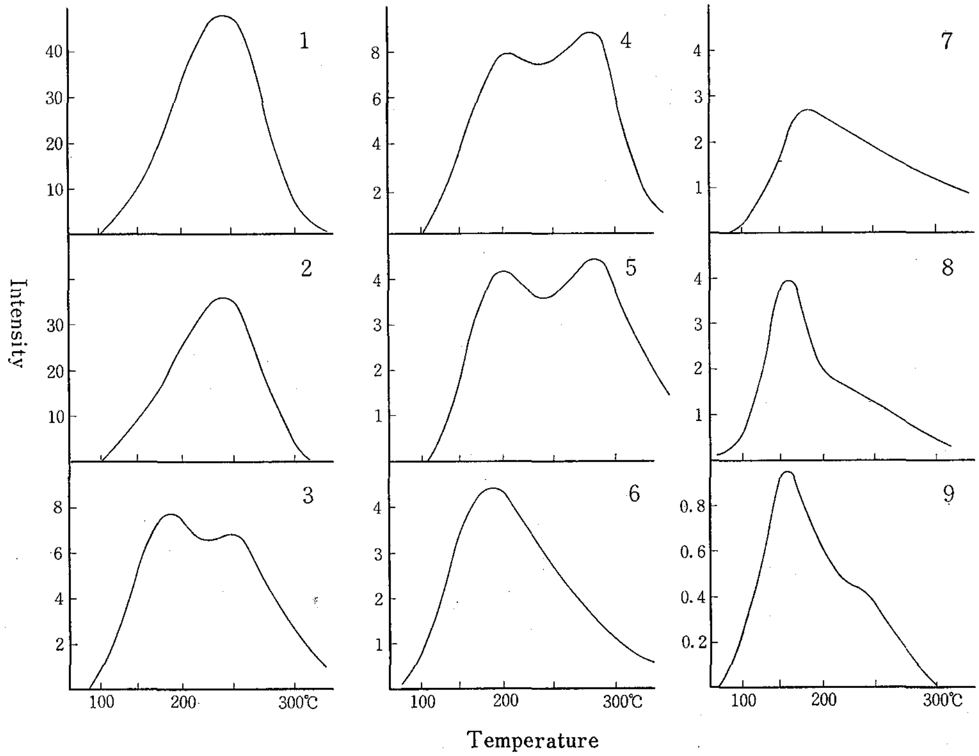

Fig. 1. The glow curves specific to the type of rock.
1. Dacite, Muro, Nara Prefecture.
2. Liparitic tuff, Kozagawa-town, Wakayama Prefecture.
3. Liparitic tuff (Welded tuff ?), Himeji city, Hyogo Prefecture.
4. Quartz porphyry, Shiroyama, Yoshida-town, Hiroshima Prefecture.
5. Quartz porphyry, Kitashirakawa, Kyoto city.
6. Biotite granite, Tokuyama city, Yamaguchi Prefecture.
7. Biotite granite, Kitashirakawa, Kyoto city.
8. Granite-gneiss, Ohyama-town, Toyama Prefecture.
9. Feldspar-biotite-quartz shist, Unazuki, Toyama Prefecture.

irradiation with gamma rays (10^4 r). When Li was diffused into quartz, glow peak appeared at 185°C and 245°C. Na-diffused quartz showed a broad peak at 280°C and quartz into which Al and Li were diffused showed a large peak at 185°C. In the case of quartz with Al, Li and Na, glow peak appeared at 185°C and at a intermediate temperature between 245°C and 280°C.

Auther found that quartz coexistent with lepidolite (Li-including mica) from pegmatite (Nagatare, Fukuoka prefecture) showed a glow peak at 250°C after gamma irradiation of 10^7 r, whereas synthetic quartz grown in sodium carbonate showed a glow peak at 290°C.* The glow peak at about 245–300°C was associated with smoky coloration as was reported.[1,8)]

According to Komov *et al.*[8)] (1971), the position of 185°C peak is variated to some content and quartz samples such glow peak are always associated with the infrared

* Unpublished.

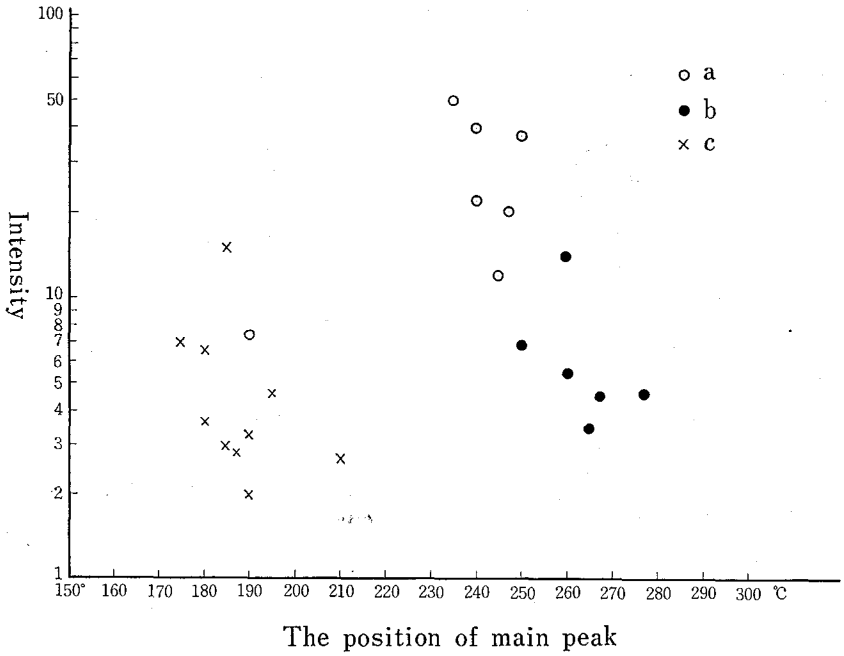

Fig. 2. Variation of the intensity and the position of main glow peak in quartz from three types of rock.
a : volcanic quartz, b : quartz from quartz porphyry or granite porphyry, c : granitic quartz.

absorption of 3487 cm^{-1} which is attributed to the vibration of OH group distorted by localized Li ions.[5,8] Dodd *et al.*[3] (1964) found that Li ion incorporated during growth of synthetic quartz occupies sites which are associated with OH ions whereas Li introduced into synthetic quartz by electrodiffusion is not associated with OH ions. Therefore, it can be said that Li ions take two positions in quartz crystal. Spectrological data of thermoluminescence and ESR data showed that thermoluminescence occurs when mobile electron recombines with hole trapped in the vicinity of Al^{3+} which replaces Si^{4+} in SiO_4 tetrahedron.[6,7]

From these data, the auther conclude that the glow peak at about 185°C and 245°C are attributed to electrons trapped at Li^{+} in Al–Li center which is consisted of substitutional Al^{3+} for Si^{4+} in tetrahedron and charge-compensating Li^{+}. Li takes two positions, one of which is associated with smoky color (245°C peak) and the other not associated (185°C peak). The glow peak at about 280°C seems to be associated with Na in Al–Na center which produces smoky color.

As for the rock quartz, the main peak of granitic quartz (185°C) is related to Li in Al–Li center which does not produce smoky color but that of volcanic quartz (245°C) is related to Li in Al–Li center which produces smoky color. The main peak of quartz from quartz porphyry or granite porphyry (260°C) is related to Al–Li and Al–Na center which produce smoky color.

When these quartz samples are irradiated with gamma rays of various doses, 185°C peak always grows in quartz from quartz porphyry or granite porphyry and granite but rarely appears in volcanic quartz. After gamma irradiation of 10^7 r, a new peak at 260–290°C appears with high intensity in granitic quartz. In volcanic quartz, no new peak is produced but the intensity of the original peak is considerably increased.

From these results of thermoluminescence in artificially irradiated and non-irradiated natural quartz samples, it is concluded that relative concentration of Al–Li center associated with smoky color is large in volcanic quartz. With decreasing the growth temperature of quartz, the concentration of this center decreases and the concentration of Al–Li center not associated with smoky color and Al–Na center increase.

In quartz samples from dynamometamorphic rocks (gneiss, shist and quartzite), the glow curve is specific in that the peak occurs at 150–165°C. This peak may be attributed to a electron trap formed by strain (Fig. 1. 8–9).

In conclusion, natural thermoluminescence is closely related to the occurrence of quartz with the exception of that from pegmatite and hydrothermal vein. Especially the difference in glow curves of quartz samples from three rock types (volcanic rock, quartz porphyry or granite porphyry and granite) seems to be associated with the content and the position of lithium and sodium ions which compensate the charge defect resulting from the replacement of Si^{4+} by Al^{3+}.

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